

# MICRO-HELM—A MISSION OPERATION VISUALIZATION SYSTEM

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## ABSTRACT

Micro-Helm is a PC based mission visualization system that can be employed for comprehensive monitoring of mission system states during operation. Micro-Helm was designed as a cost-effective system solution that can be adapted to multiple missions in various mission lifecycle phases. It has been successfully applied to DS1 mission during its entire operation phases and Mars Odyssey mission during its launch and orbit-insertion phase, providing scenario design and validation.

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## 1. INTRODUCTION

Micro-Helm system development were supported by several NASA technology programs:

- 1) Next Generation Infrastructure (NGIS) - Distributed Visualization Architecture,
- 2) Intelligent Synthesis Environment (ISE) - Virtual Mission Operation & Intelligent Mission Model Agents),
- 3) Space Science Analysis Information System (SSIS)—Model Based Mission Design.

It's a collective R&D activities led by the Mission Simulation and Instrument Modeling Group at JPL. The motivation is to provide a system solution to help in early detection of design faults and/or operation errors in the whole mission lifecycle, therefore to reduce the cost and the risk of a mission.

Micro-Helm has utilized and developed the state-of-art hardware and software to achieve its goal. Its distributed visualization capability provides comprehensive monitoring of mission system state. Its scalable PC cluster architecture makes it easy to be replicated and customized for a wide range of missions at different phases of mission lifecycle. In this paper, the infrastructure of Micro-Helm is described in Section 2.

Micro-Helm has been successfully applied to Deep Space One (DS1) mission during its entire operation phase and to Mars Odyssey mission during its launch and orbit-insertion phase, providing scenario design and validation. The application of Micro-Helm to DS1 and Odyssey are described in Section 3.

The paper is concluded with the future and ongoing activities of Micro-Helm.

## 2. INFRASTRUCTURE

Micro-Helm is designed to provide a group of visualization station to simultaneously visualize various aspects of mission operation. The cheap price of PC and its graphics capability makes PC the perfect candidate for Micro-Helm. In the case of Mars Odyssey mission, the hardware of Micro-Helm consists of a cluster of 6 Windows 2000 PCs. The CPUs are interconnected with a local area network for handling computational load of simulation. Six flat panel monitors are concatenated as a 3x2 matrix. Fig 1. Shows the Micro-Helm system for Mars Odyssey mission. The total cost of this system at year 2001 was \$50K.

One of the major challenges of Micro-Helm system lies in the software engineering area: to build a complex system that can organize a wide range of mission data products, intelligently serve derived information to multiple clients and flexibly adapt to mission needs [1]. The software of Micro-Helm is composed of two distinct layers: mission information service layer and mission operation visualization layer. Microsoft's distributed component

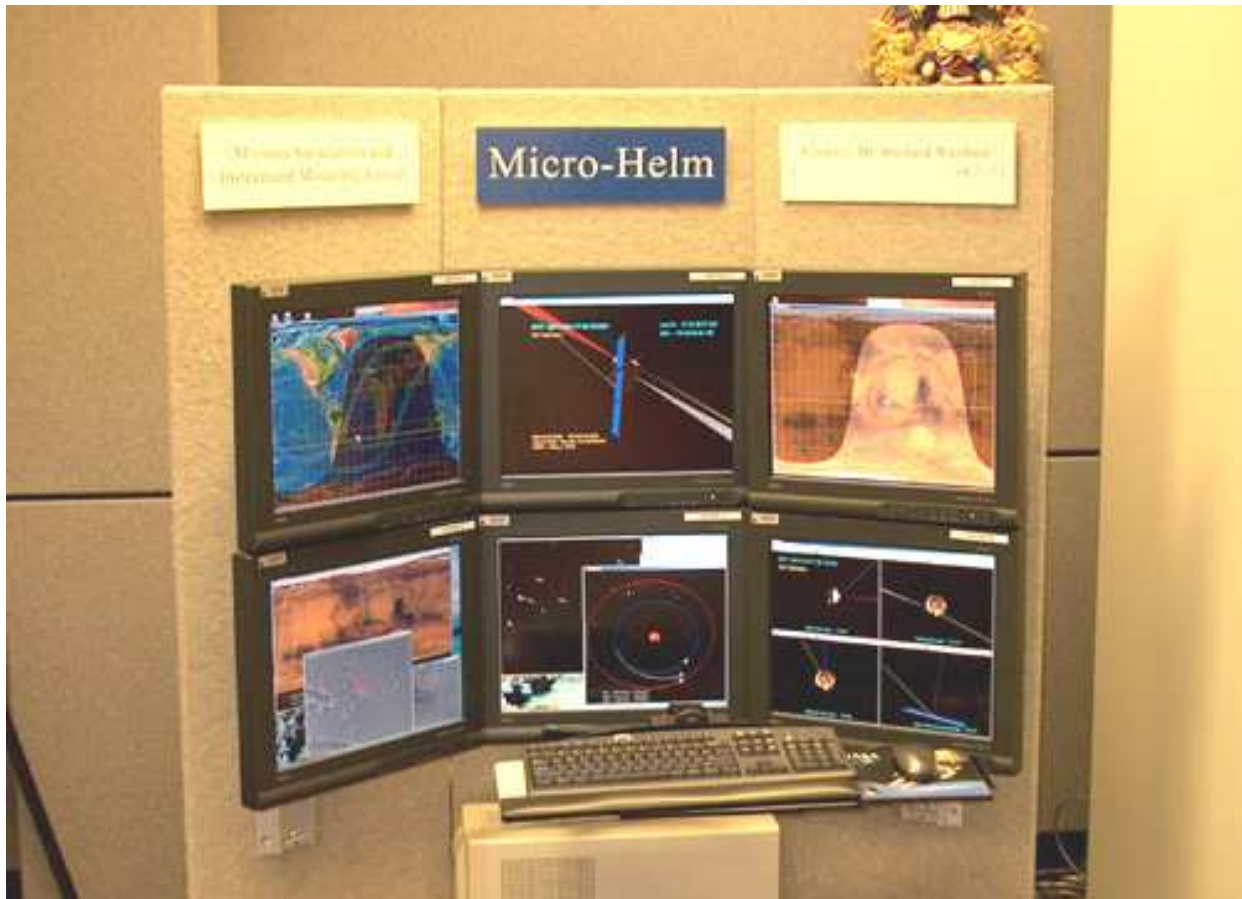


Figure 1. Setup of Micro-Helm system in Mars Odyssey Control room. The first row from left to right: DSN view, SC attitude view, Mars clock. The second row from left to right: Themis footprint, trajectory view and subsystem view.

DCOM was used as the communication mechanism between the two layers. The modules of the mission information layer serve multiple clients simultaneously while the module of the mission visualization layer performs specific visualization task.

The mission information service layer is populated with four domain-intelligent mission model agent/broker pairs: Navigation, Telemetry, Mosaic and Planet. Each agent module is knowledgeable with its domain data products and is responsible for providing a set of derived information to application clients simultaneously.

- Navigation server: handles OPTG (Orbit Propagation and Trajectory Generator) and SPK (Spacecraft-Planet Kernel) and derives relative spacecraft state with respect to a reference body.
- Mosaic Server: handles PDS (Planetary Data System) format mosaic database and interactively constructs area maps for specified latitude/longitude with different resolution.
- Telemetry Server: handles mission-specific telemetry record structure and provides SC attitude and subsystem state information.
- Planet Server: handles PCK (Planet Constant Kernel) files and derives planet kinematics for a specific time.

The technical details of the intelligent mission model agents can be found in paper "Component-based Implementation of Agents and Brokers for Design Coordination" [2].

The mission operation visualization layer is populated with a wide range of application modules for monitor the operation status from multiple perspectives: spacecraft view, instrument view, DSN schedule and spacecraft track projected on Mars and Earth. Each application can be used for prediction, real-time or post analysis, depending on the source of the telemetry data (simulated, or real-time).

- Earth Clock: presents time (UTC) and a cylindrical earth map with real-time sunlight/shade update. Earth clock marks the DSN locations and their coverage. The DSN schedule (+/- 12 hour at the time) is shown along with the spacecraft antenna pointing intersection at earth's surface. More than one spacecraft can be presented on the map for inter-mission cross-reference. (Fig 2).
- Mars Clock: presents time (UTC) and a cylindrical Mars map with real-time sunlight/shade update. Mars clock marks the sites of interests. During an orbit mission, three orbits – previous, current, next – are

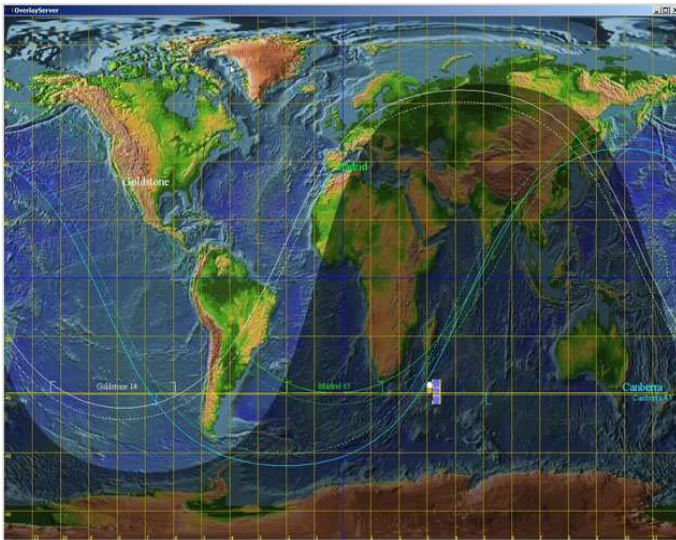


Figure2EarthClock

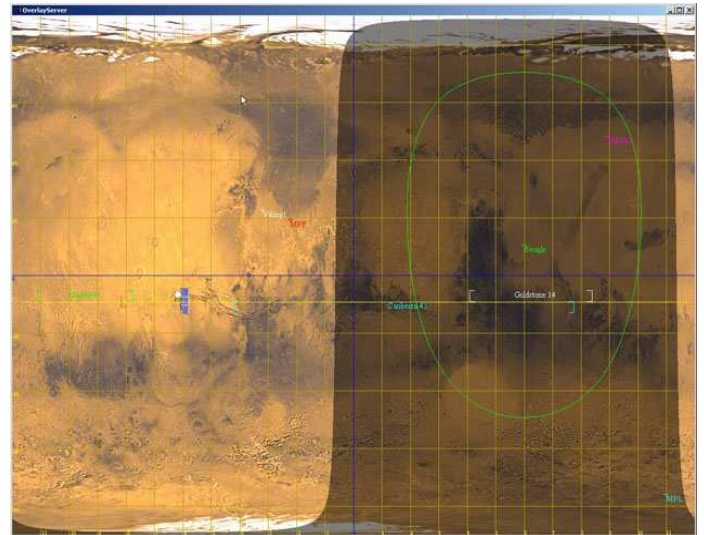


Figure3MarsClock

overlayed on the map. Up to two spacecraft's orbit track can be represented simultaneously (Fig 3).

- SC View: presents 3D spacecraft attitude, solar panel articulation, antenna articulation, antenna pointing along with the directions of earth, sun and target body. It also reports telemetry records such as earth receiving time, downlink rate etc. A set of subsystem states can be interactively chosen for monitoring, such as the angles between antenna pointing direction and the earth direction, the angle between solar-panel normal direction and the sun direction. (Fig 4, 5).
- Instrument View: presents the view from instruments including star tracker and science instruments reflecting the position and attitude of the spacecraft. For star tracker view generation, relative star intensity is observed and the names of the stars (up to 50) are indicated on the image. For the science instrument view generation, field-of-view and the detector resolution are observed for data product synthesis. (Fig 6, 7).

The software of Micro-Helm can be executed on any window platform. The flexibility to analyze different source of telemetry data (prediction, real-time, post-analysis) makes it a powerful tool for design, development and operation scenario validation at different phases of mission lifecycle.

### 3. MISSION APPLICATIONS

Micro-Helm has been applied to Deep Space 1 mission during its entire operation phase (1999 – 2000) and to Mars Odyssey during its launch and orbit-insertion phase (2000-2001).

For the Deep Space 1 mission, Micro-Helm was used in science sequence design and validation for MICAS

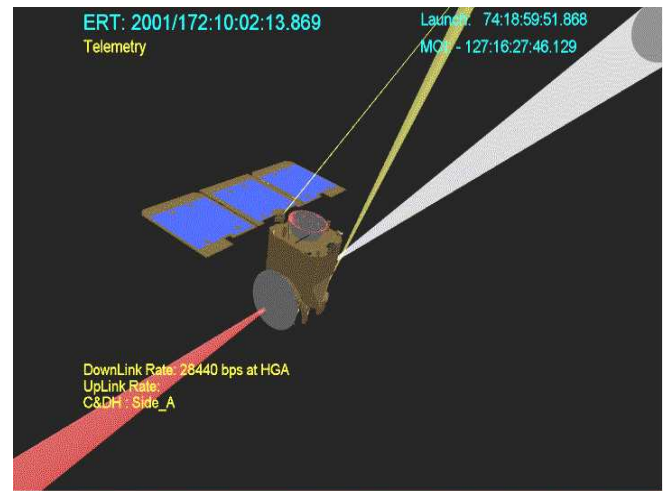


Figure4SCattitudeandarticulationview

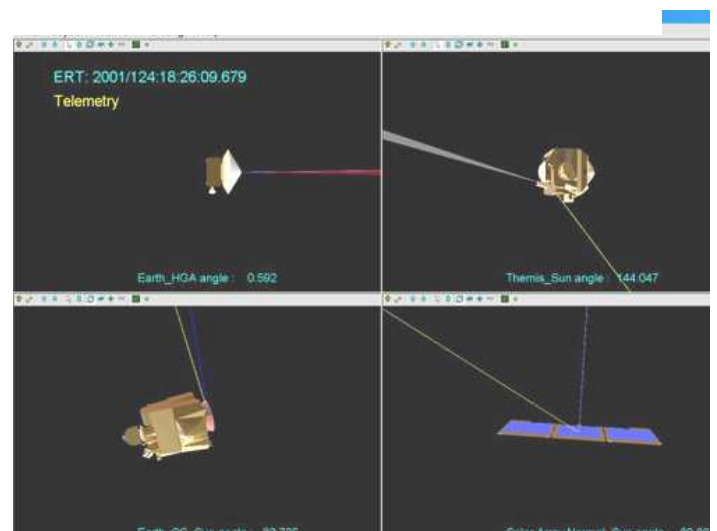


Figure5SCsubsystemview





Figure6StarTrackerview

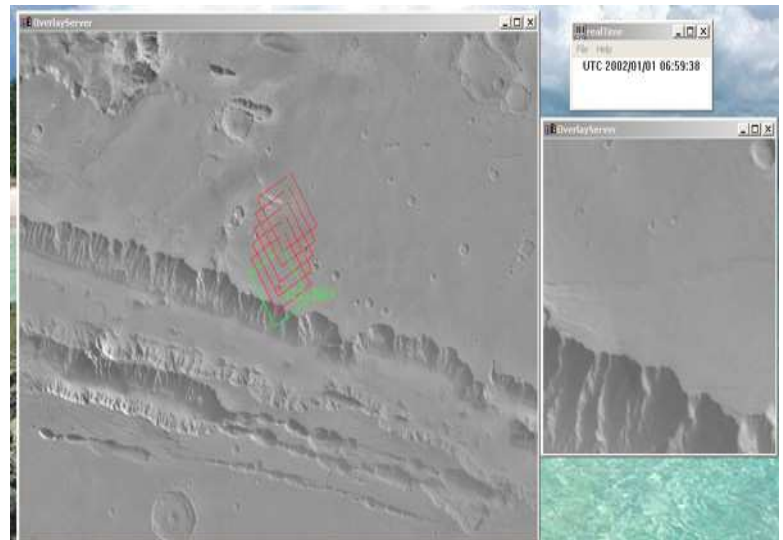


Figure7FootprintofOdysseyinstrumentTHEMIS.

instrument during flight calibration, Asteroid Braille encounter and comet Borrelly encounter [3]. Before each event, extensive simulation was studied for sequence design and simulated data were visualized through Micro-Helm to test the feasibility of the designed sequence. The designed sequences were tested in test-bed and Micro-Helm provides visualization channel for its test-bed data and validate its results comparing with the simulation data. After real event data is collected, Micro-Helm provides comprehensive analysis and validation of these data through its visualization.

Micro-Helm played an important role in the success of DS1. During the comet Borrelly encounter, Micro-Helm was providing MICAS sequence analysis and validation on a daily basis. Fig 8 shows a simulated MICAS calibration sequence comparing with its real data. The target trajectory is projected on the instrument field-of-view map. The agreement between the simulation and real data provided a strong validation of these sequence scenario design.

Application of Micro-Helm to Mars Odyssey mission was reported as one of the highlight accomplishment of NASA information technology program in 2000.

During Mars Odyssey mission (launch and orbit-insertion phase), it was used as a real-time telemetry visualization station providing continuous monitor (24 hours a day, 7 days a week) of the spacecraft system state. Micro-Helm station was set up in the Mars Odyssey control room. Socket communication was established between Micro-Helm and Odyssey GDS (Ground Data System). Broadcasted real-time telemetry data were sent to Micro-Helm station and visualized within seconds. Micro-Helm was also used during ORT (Operation Readiness Test) to verify the simulated operation. Off-line data can be

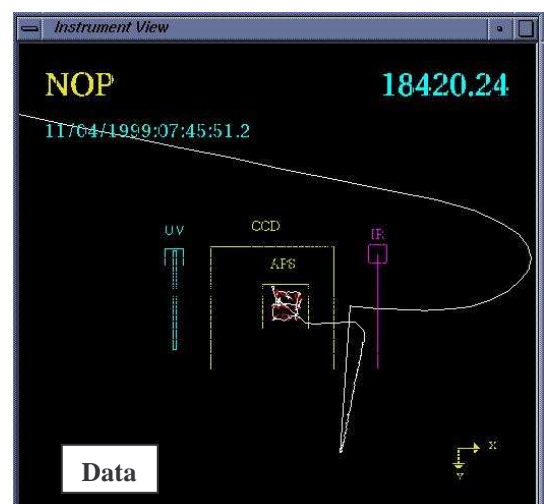
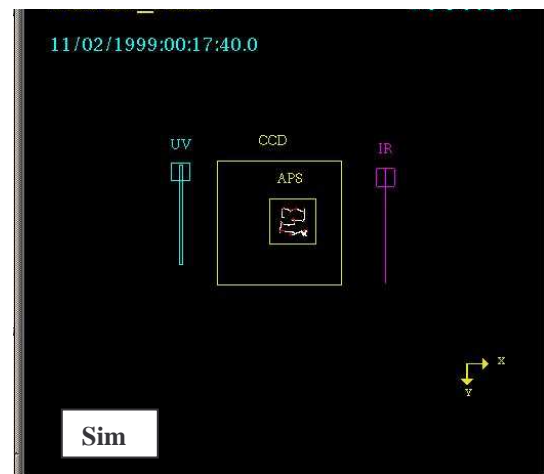


Figure 8 shows a simulated sequence comparing with the real data. The white line is the target trajectory projected on the instrument field-of-view map

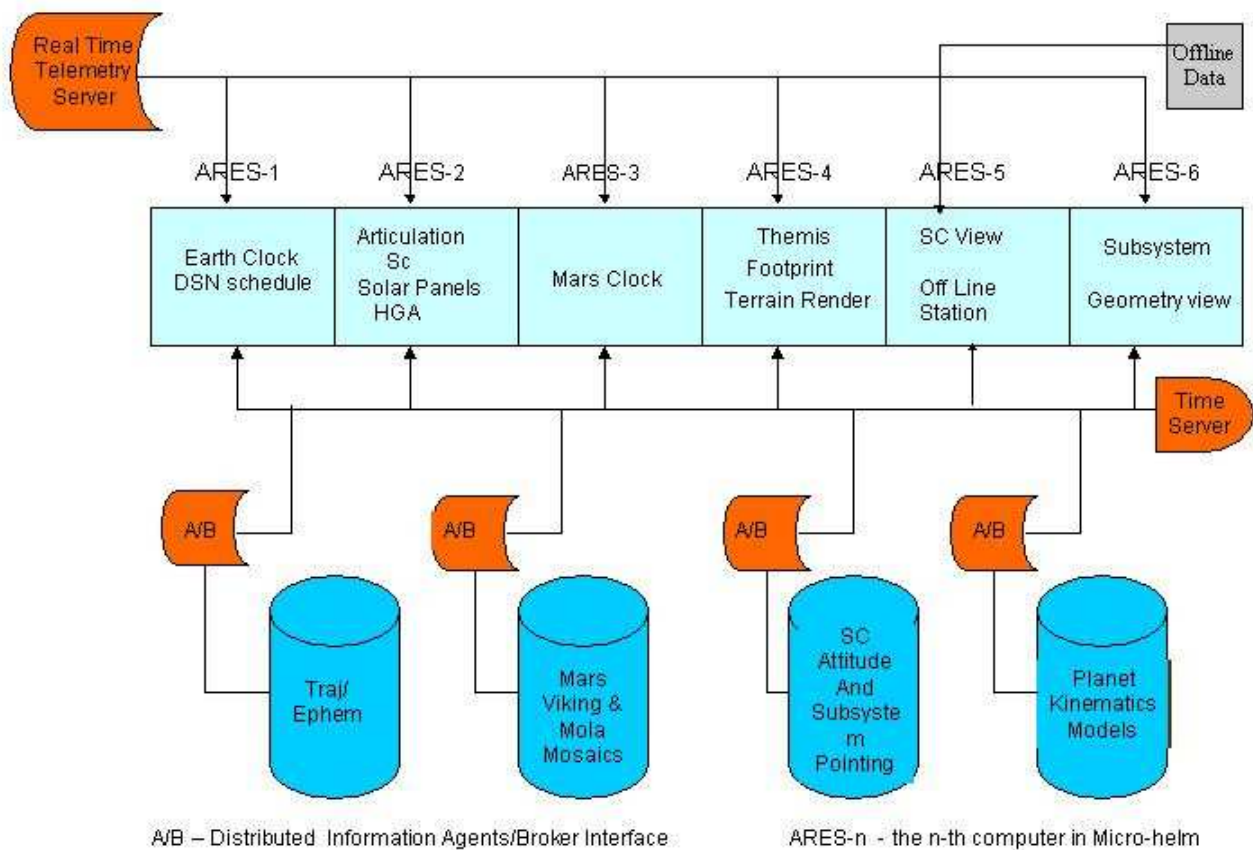


Figure 9 Micro-Helm configurations for Mars Odyssey Mission

retrieved through query channel and analyzed by Micro-Helm whole system or can be analyzed on the off-line station (ARES-5) if it's a standalone telemetry data file. During MOI, Micro-Helm was one of the first systems that reported the health of spacecraft. Fig 2 shows the setup of Micro-Helm in the Odyssey control room. Fig 3, Fig 4, Fig 5, Fig 6 and Fig 7 show the details of different visualization window. Fig 9 depicts the configuration of Micro-Helm for Mars Odyssey mission.

simultaneously. And multiple states can also be projected into an integrated system state.

Micro-Helm has demonstrated its easy adaptability to different phase of mission life cycle. Currently Micro-Helm is used as a science-return validation platform during concept design phase in collaboration with Team-X. The comprehensive monitoring of a mission during early design phase is essential for assuring the operation feasibility of the mission and for maximizing the science return.

#### 4. CONCLUSION

The experiences of Micro-Helm with Deep Space 1 mission and Mars Odyssey mission have proved that Micro-Helm is a powerful validation tool and a cost-effective system solution. It provides a supercomputing environment for scientists, mission operators and mission designers. It enables comprehensive understanding of a mission among multi-discipline teams. A spacecraft system state can be viewed from different subsystem perspectives

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